International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

A REVIEW OPTIMIZED DESIGN GUIDELINES AND CONSTRUCTION PRACTICES FOR ELEVATED WATER TANKS

Kishor Buwade[1], Vinay Kumar Singh Chandrakar[2],

****M.Tech. Scholar[a], Associate Professor[b], Madhyanchal Professional University, Faculty of engineering & Technology, School of civil engineering Bhopal, M.P., India. ****

Abstract
Elevated water tanks play a crucial role in water distribution systems, ensuring a consistent supply of potable water in urban and rural areas. The design and construction of these structures require careful consideration of structural stability, material selection, seismic resilience, and cost-effectiveness. This study focuses on optimizing the design and construction practices of elevated water tanks to enhance durability, efficiency, and safety. The research presents innovative methodologies, including advanced structural analysis, modern construction techniques, and sustainable material choices, to improve the overall performance of water tanks. By incorporating optimization strategies, this study aims to provide practical guidelines that contribute to the long-term functionality and resilience of elevated water storage systems.

.

Key Words:- Elevated water tanks, material selection, seismic resilience, cost-effectiveness, overall performance of water tanks

Introduction

Water tanks are essential for storing water for various applications, including drinking, irrigation, agriculture, fire suppression, livestock farming, chemical manufacturing, and food preparation. The design of a water tank plays a critical role in ensuring long-term efficiency, durability, and sustainability. The capacity of the tank must be determined based on projected water demand, considering population growth and future requirements. Overhead water tanks typically have a lifespan of 20–30 years, requiring careful planning to accommodate increasing demand over time. Durable, resistant to environmental conditions, and widely used for large-capacity storage. Lightweight, corrosion-resistant, and commonly used for small to medium storage capacities. Depends on the volume of stored water, varying between empty, half-filled, fully filled, and overflow conditions. Circular, rectangular, and spherical tanks, each designed for specific applications based on efficiency and structural behavior. A well-designed water tank ensures the efficient storage and supply of water while accounting for structural integrity, future growth, and environmental conditions. Proper material selection, load analysis, and adherence to design codes are crucial to ensuring longevity and reliability. Circular tanks are more efficient in terms of formwork. Since the shape is symmetric, it requires fewer labor hours and materials to construct the formwork. This design is also advantageous when it comes to minimizing the surface area exposed to external pressures, which is why it is often preferred for water storage. The study found that the **Limit State Method** is more economical for the design of water tanks. LSM takes into account the safety and serviceability limits of the tank under various conditions, such as load-bearing capacity, durability, and performance under extreme loads (like earthquake or water pressure). This method results in **less steel usage** because it allows for a more accurate prediction of the tank's behavior, especially at the limits of its capacity.

Working Stress Method (WSM): In contrast, the **Working Stress Method** is based on ensuring the tank remains below certain stress limits during normal operation. This method tends to be more conservative, leading to the use of more material and steel reinforcement than is necessary according to the LSM. As a result, LSM is more cost-effective and efficient in terms of material utilization.

Rectangular tanks resting on the ground with dimensions like **8x5x2.5** offer a good balance between structural performance and cost-efficiency.

Circular tanks are the best for reducing formwork costs and complexity.

The **Limit State Method** is more economical than the Working Stress Method, as it uses less steel and better predicts the actual performance limits of the tank.

Literature Review

Mr. Meet Dama et al (2023) working on the structural analysis of a circular water tank on sloping ground, considering wind and seismic loads as per IS 1893:2016 and IS 875:2015 (Part 3) using STAAD.Pro V8i. This is an important study for ensuring the safety and stability of elevated storage tanks under extreme loading conditions. How the sloping is ground affecting the base support of the tank. Are you considering soil-structure interaction. Are you considering dynamic wind response or only static wind pressure for different wind speeds (39 m/s and 44 m/s). Since you're analyzing for Zone V, are you including hydrodynamic effects (sloshing forces) in your seismic calculations storage tanks play a crucial role in various industries, and their design must consider multiple factors, including structural integrity, seismic resilience, wind loads, and blast resistance, especially for large storage tanks. Some key points related to the design of storage tanks include. Tall storage tanks need to resist wind-induced overturning moments and lateral forces.

Abhinav Kumar Anand et al (2023) the design and analysis of elevated water tanks are crucial for ensuring their structural integrity and performance. This study presents an investigation into the design and analysis of an elevated water tank using STAAD Pro, a widely-used structural analysis and design software. The objective is to assess the structural behavior and performance of the water tank under various loading conditions and optimize its design for safety and efficiency. The analysis starts with the selection of suitable materials and dimensions for the water tank, considering factors such as capacity, site conditions, and design standards. The structural model of the tank is then developed in STAAD Pro, incorporating appropriate boundary conditions and loading scenarios, including dead loads, live loads, wind loads, and seismic loads. The software allows for accurate modeling of the tank's components, such as the tank shell, columns, base slab, and support structure. The study evaluates the structural response of the water tank through various analyses, including static analysis, dynamic analysis, and stability analysis. STAAD Pro provides advanced analysis capabilities to assess the effects of different load combinations, determine the critical locations, and identify potential failure modes. The analysis results guide the design modifications and reinforcements required to enhance the tank's overall stability, strength, and durability. The study also considers important design considerations, such as water pressure, temperature variations, and corrosion protection measures. By incorporating these factors, the final design aims to ensure the safety and functionality of the elevated water tank while minimizing maintenance requirements and lifecycle costs. Through this research, the design and analysis process using STAAD Pro for elevated water tanks can be further understood and improved. The findings contribute to the development of optimized design guidelines and construction practices for elevated water tanks, which are essential for reliable water storage and distribution systems.

Anand Khune et al (2023) Water is a basic human necessity, and an efficient water distribution system is essential to ensure a continuous and reliable supply. The design of water storage tanks plays a critical role in meeting the water demands of a specific area. Water storage tanks are essential structures used to store water for domestic, industrial, and firefighting purposes. They ensure that water is available when needed, helping to regulate the supply during peak and off-peak demand periods. During periods of low demand, water is pumped into the storage tank to be stored for later use. Conversely, during periods of high demand, water is pushed out of the storage tank into the distribution system, ensuring a consistent supply. These storage tanks help to maintain pressure stability, reduce energy costs, and ensure availability in case of emergencies. Water storage tanks are designed in various forms based on their application, location, and required storage capacity. Water storage tanks must be designed to withstand hydrostatic pressure, seismic forces, wind loads, and soil pressure (for underground tanks)**.** Various materials such as reinforced concrete, steel, and fiber-reinforced plastics are used depending on the project requirements. STAAD.Pro (Structural Analysis and Design Program) is a widely used software for analyzing and designing various structural systems, including water storage tanks. It helps structural engineers perform 3D structural analysis and design for steel and concrete structures efficiently.

Katari Yogeshwar et al (2022) every design comes out when there is a problem. A design is created to solve the existing problems. People in the region where there is scarcity of water, don’t get enough flow or speed or discharge especially those living on the upper floors in a multi-storied building. As a consequence people suffer from lack of water due to insufficient supply for compensating their daily needs. As a first solution of this problem, one needs to develop a water storage project as has been designed with the help of STAAD principles, known as Overhead Water Reservoir. The present study reports the analysis and design of an elevated circular water tank using STAAD.Pro V8i. The design involves load calculations manually and analyzing the whole structure by STAAD.Pro V8i. The design method used in STAAD.Pro analysis is Limit State Design and the water tank is subjected to wind load, dead load, self – weight and hydrostatic load due to water.

Deepshikha Gadekar et al (2022) Water tanks and reservoirs are essential structures used for storing water, petroleum, and chemicals for domestic, commercial, and industrial purposes. An underground water tank is designed to store water while maintaining a stable temperature and providing an efficient system for pumping water to an overhead tank. In this project**,** a rectangular underground water tank with a capacity of 2 lakh liters (200 cubic meters) is designed following IS code norms. The design incorporates structural stability against lateral earth pressure and hydrostatic water pressure. The analysis and design are performed using STAAD.Pro, and the Limit State Method (LSM) is applied for structural safety. The design of an underground water tank involves the analysis of various forces, materials, and load conditions as per IS 3370:2009 and IS 456:2000**.**

M. Ravikanth et al. (2019) highlights the importance of seismic considerations in the design of hydraulic water tanks using STAAD-Pro. Their approach focused on optimizing the tank's structural design while ensuring economic feasibility. The key findings include. The influence of seismic loads in different seismic zones (II, III, IV, and V) on the design parameters of circular water tanks. The variation in steel and concrete requirements across seismic zones. The conclusion that designing a water tank in Zone V (the highest seismic risk zone) is significantly more expensive due to increased reinforcement and structural requirements. This research provides valuable insights for engineers involved in the structural design of water tanks, particularly in seismic-prone regions. Would you like a more detailed breakdown of the methodology or any specific insights.

Issar Kapadia et al. (2018) introduced an innovative concept by designing and analyzing a combined rectangular water tank**,** where an overhead rectangular water tank is integrated with **a** rectangular surface water tank into a single structure. The study was carried out using STAAD-Pro software, a widely used structural analysis and design tool. Instead of constructing two separate water tanks (one overhead and one ground-level), they designed **a** single combined structure that consists of the research used Finite Element Analysis (FEA**)** within STAAD-Pro to assess structural behavior under different load conditions. Successfully demonstrated that combining an overhead rectangular water tank with a surface rectangular tank into a single structural system results in lower hydrostatic pressures, reduced deflections, and improved performance compared to conventional separate tank designs. The use of STAAD-Pro for analysis validated the feasibility and efficiency of the combined design.
This research provides valuable insights for engineers and designers looking for innovative and efficient water storage solutions in urban and rural infrastructure projects.

Mareddy Arunkumar et al (2018) paper we mentioned focuses on the design and analysis of an overhead circular water tank, aiming to ensure safety and avoid cracking, particularly for a large capacity of 15 lakh liters (1.5 million liters) at a height of 15 meters. The use of STAAD Pro software for the structural analysis and design of such a tank is common due to its powerful capabilities in handling complex loadings and structural behavior.
The key aspects likely discussed in the paper include.

Structural Analysis: Evaluating the behavior of the tank under various loading conditions such as dead loads, live loads, seismic forces, and wind loads.

Design of Tank Components: This would involve designing the base slab, shell, and roof of the tank to withstand the pressure exerted by the stored water, as well as ensuring the structural integrity against external forces.

Crack-Free Design: The paper likely presents methods to avoid cracking, such as the use of proper reinforcement, the inclusion of expansion joints, and attention to concrete mix design and curing processes.

Software Application: STAAD Pro is a widely used software for structural design and analysis, which allows for detailed modeling and simulation of the tank to predict its behavior under various conditions and optimize the design to prevent cracks or failure.

Shreya Salunke et al. (2017) conducted a study titled **"**Analysis of Solid and Hollow Wall of Circular Steel Petroleum Tank for Stress in STAAD-Pro." This research aimed to analyze a storage tank with a capacity of **1.5** lakh liters of hazardous petroleum liquid. The study adhered to relevant standards and design codes, selecting materials in compliance with the latest IS codes and adopting an appropriate design methodology. The storage tank's design specifications were outlined, considering two types of tanks—hollow and solid—with identical thicknesses. The tank design followed IS codes, with a nominal diameter of 12m **a**nd **a** height of 14.1m, without any space constraints. The number of courses was specified, with the bottom plate thickness set at 8mm, and carbon steel (IS 2062:1969) chosen as the material. The study found that the maximum absolute stress in the solid tank was lower than in the hollow section. As theory suggests, with an increase in deformation**,** the hollow tank exhibited greater deformation compared to the solid tank.

Patel Nikunj R et.al (2016) this study presents a parametric analysis of an overhead rectangular concrete water tank subjected to different static loading conditions. The authors used STAAD **Pro** software to analyze and design the structure while considering the provisions of **IS** 3370 (Indian Standard for concrete water tanks) **and** PCA (Portland Cement Association) guidelines**.** The study primarily focuses on understanding the effect of aspect ratio, support conditions, wind loads, fluid density, and load combinations on the overall stability and performance of the water tank. The study investigates how the aspect ratio (length-to-breadth ratio) of a rectangular water tank affects its structural behavior. Tanks with different aspect ratios were analyzed, keeping the same storage capacity constant. The end conditions (fixed, hinged, or simply supported) play a major role in governing the stiffness and deflection of the tank. It was found that deflections increase significantly when supports settle**,** which can lead to structural instability. When the support of the tank settles, the load redistribution leads to excessive deflection. This deflection is higher in long-span tanks compared to square or near-square tanks. Increased deflection affects the serviceability and durability of the tank, making it more susceptible to cracks and leakage**.** Tanks with higher elevation and large surface areas experience greater wind pressure, which can cause oscillations and structural instability. This study provides valuable insights into the structural behavior of overhead rectangular water tanks under different loading conditions. The findings can help engineers optimize the design and enhance the safety, durability, and efficiency of such structures**.**

Thalapathy M et al (2016) focuses on analyzing and designing water tanks in an economical and efficient way based on different types of tank positioning and geometries. Here's a detailed explanation of the key points and conclusions of the study. These tanks are buried below the ground, and their design must account for soil pressure, water pressure, and possible seismic forces. They usually require robust structural design to withstand external pressures. These tanks are positioned on the surface, where structural design considerations include uniform distribution of weight, resistance to external forces, and ease of construction. These tanks are elevated above the ground and have to support their own weight as well as the weight of the stored water. They must be designed to resist wind, seismic forces, and water pressure. The study concludes that the height-to-diameter ratio of 0.45 is the most suitable for economical and safe design. This means that for a given tank, the height should be 45% of its diameter. This ratio optimizes the structural strength and minimizes material costs by balancing the height and diameter, ensuring the tank remains stable under pressure. The study found that rectangular tanks with dimensions of 8x5x2.5 meters have moderate shear forces, bending moments, and deflections. These values are considered manageable, meaning the structure can resist these forces without excessive material usage or need for reinforcement. The 8x5x2.5 rectangular tank was deemed the most economical in terms of construction costs for tanks resting on the ground. This is likely due to the relatively simple construction and the material efficiency of this design. As the tank is placed on the ground, the shear force and bending moments decrease as one moves downward. This suggests that the structural requirements become less intense deeper into the tank's design, making the lower sections less demanding in terms of reinforcement and material use.

M. Bhandari et al. (2014) in their study "Economical Design of Water Tank of Different Shapes with Reference to IS-3370:2009" focused on comparing the structural and material efficiency of water tanks with various shapes—circular, square, rectangular, and Intze tanks. The study was conducted with respect to IS 3370:2009, which governs the design and construction of concrete water tanks in India. The main objective of the study was to design water tanks of different shapes and volumes (100,000; 150,000; 200,000 liters) using the limit state method of design and to determine the most economical design based on the amount of material used and the overall construction cost. This method was used for designing the water tanks to ensure safety and serviceability requirements. The limit state method is a more modern approach, ensuring that both the strength and the stability of the structure are adequate under loading conditions. The tanks were designed for three different volumes of 100,000 liters, 150,000 liters, and 200,000 liters, and the results were compared for each. The cost and quantity of formwork needed for each type of tank, as formwork is an important factor in construction costs. The structural efficiency, including factors like load distribution and the ability to resist internal water pressure. The circular tank consumed the least amount of material compared to the square, rectangular, and Intze tanks. This is mainly because the circular shape naturally distributes the internal water pressure more efficiently. The geometry of a circle leads to a more uniform stress distribution, requiring less reinforcement and concrete. The square and rectangular tanks have more complex geometries that lead to higher material consumption, particularly in the corners, where stresses tend to concentrate. The Intze tank, which has a more complex and irregular shape, required the most materials due to its additional structural components like the conical base and sloping walls. This added to the overall complexity of the design, increasing the material usage. The circular tank required the least amount of formwork compared to the other shapes. The reason for this is that the circular form is continuous and simple to construct with minimal formwork complexity, reducing the time and labor required for construction. For square and rectangular tanks, the formwork requirements are higher because of the need for more intricate details, especially at the corners and edges. Intze tanks required even more formwork due to their irregular shape, including the need for special molds for the conical and sloped surfaces. The **circular shape** is inherently more structurally efficient because the stress distribution is uniform across the structure. This reduces the need for additional reinforcement, making the design more material-efficient. Have weaker points in their design, especially at the corners, leading to higher reinforcement requirements. The edges experience more stress, which leads to greater material consumption.

Yogeshkumar Bajpai et al. (2009) highlights the key revisions in the design standards for water tanks in India, particularly comparing the earlier IS 3370 (1967) and the revised IS 3370 (2009). The significant change was the introduction of the Limit State Design (LSD) method alongside the traditional Working Stress Method (WSM), which was the sole method in the 1967 version. The adoption of LSD was intended to enhance the structural integrity and durability of water tanks, particularly to prevent the formation of cracks during the design and service life.

Reduction in Permissible Stresses in Steel: The permissible stress in steel was reduced to 135 MPa, aligning with modern practices and ensuring more controlled reinforcement in the structure.

Modifications to Minimum Steel Requirements: The clause regarding the minimum amount of steel was modified, likely aiming to optimize the structural design and reinforce the tank's durability while addressing cracking issues.

Focus on Cracking Prevention: The introduction of LSD aligns with a more modern approach to crack control in liquid-retaining structures, ensuring that the water tanks are safer and more reliable under varying load conditions.

These changes in IS 3370 (2009) reflect a significant step forward in the design practices for water tanks, offering more flexible, efficient, and safer design guidelines. The shift towards the Limit State Design method also encourages engineers to design structures that perform better under both service and ultimate conditions, ensuring better long-term performance of water tanks.

Sudhir Jain et al (1991) revised IS code for seismic design of elevated water tank. They derived simple expressions, which allow calculations of staging stiffness, and hence the time period, while incorporating beam flexibility. They give the value of performance factor 3 for the calculation of seismic design forces. The earthquake design criteria will be incomplete, unless clear specifications are include about how to calculate the time period. A method for calculating the staging stiffness which including beam flexibility and without having to consider finite element type analysis has been presented. This method is based on well-known portal method which has been suitably developed to incorporate the beam flexibility and the three dimensional behavior of the staging.

Anestis S. et al. (1992) focused on dynamic response of flexibility supported liquid storage tanks. Also critical responses are evaluated for harmonic and seismic excitations over wide ranges of tank proportions and soil stiffness, and the results are used to elucidate the effects of soil-structure interaction. It is shown that soil-structure interaction may reduce significantly the critical responses of broad tanks, but may increase those of tall, stiff tanks that have high fundamental natural frequencies. It is further shown that for tanks with height-to-radius ratios of the order of 1.5 or less, the higher modes of vibration are insignificant contributors to the overall response.

Haroun et al. (1992) were studied dynamic soil-tank interaction under horizontal seismic excitations. It has a profound effect on the amplification of hydrodynamic forces and moments exerted on tank structure. Computer programs are implemented to evaluate the system response to ground earthquake motions. The results shows that interaction of the tank and foundation soil magnifies the tank response, and it is a factor of both the shear-wave velocity of soil (higher magnifications for soft soils) as well as the geometric properties of tank (higher magnification for tall tanks). In addition, the results indicate that shell flexibility has a pronounced influence on the dynamic behavior of tanks; it contributes to the magnification of pressures developed in liquid and exerted on tank, thereby increasing the base shear and overturning moment, especially for stiff soils

Methodology

Literature Review: A comprehensive review of existing design standards, including IS 3370, ACI 350, and Euro code 2, along with recent research on material advancements and structural optimization.

Structural Analysis: Finite element modeling (FEM) to analyze various tank geometries and support structures under different loading conditions, including wind, seismic, and hydrostatic pressures.

Material Selection: Comparative analysis of conventional and high-performance materials such as fiber-reinforced concrete, prestressed concrete, and corrosion-resistant reinforcements.

Seismic and Wind Load Considerations: Evaluation of the impact of seismic activities and wind forces on the stability of elevated tanks, with recommendations for appropriate bracing and damping mechanisms.

Construction Practices: Assessment of different construction methods, including precast and cast-in-situ techniques, to determine the most efficient and cost-effective approach.

Optimization Techniques: Application of optimization algorithms to determine the most efficient tank dimensions, reinforcement details, and structural arrangements for maximum strength and minimum material usage.

Case Studies: Analysis of real-world elevated water tank projects to validate the proposed optimization strategies and assess their practical feasibility.

Conclusion

This study provides optimized design guidelines and best construction practices for elevated water tanks, addressing key structural and material challenges. The findings highlight the importance of integrating advanced structural analysis tools, sustainable materials, and efficient construction techniques to enhance the performance and longevity of water tanks. Seismic and wind resilience, along with cost-effective design strategies, are critical factors in ensuring the reliability of these structures. By implementing the proposed guidelines, stakeholders can achieve improved safety, durability, and sustainability in water storage infrastructure, ultimately leading to more efficient water distribution systems.

The structural design of water tanks is a critical aspect of ensuring a reliable and safe water distribution system**.** STAAD.Pro plays a significant role in facilitating accurate, efficient, and code-compliant structural analysis and design. With its ability to handle complex load conditions, seismic analysis, and optimization, STAAD.Pro is a valuable tool for engineers designing water storage structures. Elevated water tanks are essential for water supply distribution, ensuring consistent pressure and storage. Optimized design and construction practices enhance structural performance, durability, and cost-effectiveness.

References

1. Mr. Meet Dama, Prof. Ayyazoddin Shaikh "Effects of Sloping Ground on Analysis of Cicular Water Tank" International Journal of Research in Engineering and Science (IJRES) ISSN (Online): 2320-9364, ISSN (Print): 2320-9356 www.ijres.org Volume 11 Issue 10 ǁ October 2023 ǁ PP. 156-162

2. Abhinav Kumar Anand*1, Abhinav Sharma*2, Divya Gupta*3, Shakir Hasan*4, Shariq Shameem*5, Mr. Ankit Soni* "appendix 2 design and analysis of rcc water tank by using stadd pro" International Research Journal of Modernization in Engineering Technology and Science (Peer-Reviewed, Open Access, Fully Refereed International Journal) Volume:05/Issue:05/May-2023 Impact Factor- 7.868 www.irjmets.com

3. Anand Khune1 , Krishna Natikar2 , Mohit Bhujbal3 , Satish Wabale4 , Prof. Swapnil Bijwe "Design of RCC Well Using StaadPro Software" International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538 Volume 11 Issue II Feb 2023- Available at www.ijraset.com

4. Deepshikha Gadekar1 , Rakesh Patel "Design and Analysis of Under Ground Water Tank Considering Different Fill Conditions Using STAAD.PRO" International Journal of Scientific Research in Civil Engineering © 2022 | IJSRCE | Volume 6 | Issue 1 | ISSN : 2456-6667

5. Katari yogeshwar1 , Tsurendra "Analysis and design the circular water tank using staad pro" International Journal of Advance Research in Civil Engineering Volume 12, Issue 09, Sept 2022 ISSN 2581 – 4575 Page 51

6. M.Ravikanth, V. Mallikharjuna Reddy, S.Raja Ravindra kumar "Design and Analysis of Hydraulic Water Tank by using STAADPro" E-ISSN: 2321-9637 ICTEC March-2019.

7. Shreya Salunke, Dr. S.K.Kulkarni, Prof V.A Kadlag - "Analysis of solid and hollow wall of circular steel petroleum tank for stress in STAAD-Pro". E-ISSN:2395-0056 Volume 04 Issue 06 June-2017

8. Prof. Patel Nikunj R -"Analysis of rectangular water tank and its behavior under different types of loading by using STAAD Pro." ISSN-2250-1991 Volume 5 Issue 8 August-2016

9. Issar Kapadia, Purva Patel -"Designed Analysis and Study of the combined Rectangular Water tank: Combination of the rectangular overhead water tank and the rectangular surface water tank in combination by using STAAD-Pro". ISSN-0975-833X Volume 10 Issue 04 April-2018

10. M.Bhandari -"Economical design of water tank of different shapes with reference to IS-3370 2009" IJMER- 2014

11. Mareddy Arunkumar, O.Sriramulu,N. Venkateswarlu - "Planning, Analysis and design of a overhead circular water tank in N.B.K.R.I.S.T using STAAD Pro Software." JETIR Volume-5,Issue-5 May-2018

12. Thalapathy.M , Vijaisarathi.R .P,Sudhakar.P -Analysis and economical Design of water tank" IJISET-Volume-3 Issue-03 March 2016.

13. Shriram Nagorao Bengal ,Sandip A. Tupat- "Seismic analysis of elevated water tank with variation in H/D ratio and container shape" IJCSMC, Volume-6,Issue-5 May-2017.

14. Yogeshkumar Bajpai , Saurabh Pare-"Comparison of design of water tank as per IS 3370 (1967) and IS 3370 (2009)" ICRTESM-16, December 2016.